ANL/NE-15/15

Irreversible Wash Aid Additive for Cesium Mitigation

WARRP Demonstration and Lessons Learned

Nuclear Engineering Division

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by
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Acknowledgments

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The energy, ingenuity, and enthusiasm of personnel from multiple departments within the City of Denver were vital to the success of this demonstration.

D. Barkemeyer, senior technical representative for domestic deployments at HESCO Global, worked closely with the demonstration team. The team from Separmatic Systems participated in the demonstration described herein. A representative from C&S Supply, Inc., participated in the demonstration to provide, as needed, technical assistance with the equipment that they supplied. Their contributions in carrying out the demonstration in Denver are gratefully acknowledged, as well as their participation in planning activities for the demonstration.

Contributions of the following individuals and organizations to the development of this document are acknowledged:

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  - Paul Lemieux for preparation of the embedded video.

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List of Acronyms and Abbreviations

COTS	commercial off-the-shelf
DHS	United States Department of Homeland Security
EPA	United States Environmental Protection Agency
ft	feet
gpm	gallon per minute
IWAA	Irreversible Wash Aid Additive system
in.	inches
LAKOS	LAKOS centrifugal filter
LLRW	low-level radioactive waste
SDS	Sodium dodecyl sulfate, also commonly known as sodium lauryl sulfate
UASI	Urban Area Security Initiative
WARRP	Department of Homeland Security's Wide Area Recovery and Resiliency Program
WERF	Water Environment Research Foundation

IRREVERSIBLE WASH AID ADDITIVE FOR CESIUM MITIGATION — WARRP DEMONSTRATION AND LESSONS LEARNED

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Executive Summary

The Irreversible Wash Aid Additive (IWAA) system has been under development by the U.S. Environmental Protection Agency (EPA) and Argonne National Laboratory (Argonne). The purpose of this system is, in the event of a radiological contamination event in an urban environment, to restore functionality to basic services, immediately reduce exposure of response personnel to radiation, and reduce the longer term consequences of the event. The process consists of three primary unit operations—wash down, followed by collection and filtration of resulting wash waters. Optimization of the wash-down process was performed in a laboratory using radioactive cesium-137. To investigate the practical application of the system, an IWAA system using commercial off-the-shelf technology was demonstrated at the pilot-scale level with a simulation of radioactive material exposure of a fire department command vehicle in Denver, Colorado. This demonstration was part of the U.S. Department of Homeland Security's (DHS's) Wide Area Recovery and Resiliency Program (WARRP) in the Urban Area Security Initiative (http://www.warrp.org).

The purpose of the Denver demonstration was to assemble and demonstrate the primary unit operations of the IWAA system. No radioactive material was used for the demonstration. With the technologies selected, the IWAA developers coordinated with local city and public works officials, the regional EPA, and federal officials to establish a location for the demonstration and logistics for the receipt of materials and equipment in Denver. In collaboration with local public works departments and multiple vendors, the demonstration took place during the WARRP Capstone Event, held on September 13–14, 2012.

The demonstration consisted of setting up a rectangular perimeter of barriers (berms) in a local parking lot to create an area where wash down could occur and also to form a "reservoir" to contain the wash-down water. The barriers contained a Cs-137 sequestering agent. A simulated fire department command vehicle entered the bermed area via a ramp over the berm wall constructed from local fill dirt.

Once "clean", the vehicle was driven out of the reservoir. The slurry of sequestering agent and wash water was then purified by a mobile filtration system. Because the demonstration did not utilize radionuclides, the solids and liquid waste from the filtration system were collected by a public works suction truck for storage prior to disposal. With all the slurry and solution removed from the reservoir, the demonstration showed how the container materials comprising the berm can be separated from the fill material for disposal. A Denver street sweeper then completed the cleanup.

This activity demonstrated, on a practical scale, the primary unit operations for building a containment structure for radioactive wash waters, washing down a hypothetically radioactively contaminated vehicle, collecting the hypothetically radioactive slurry waste water, filtering the hypothetically radioactive wash waters, disassembling the containment, and transporting the materials for final disposition.

The regulatory and technical lessons learned from the demonstration are outlined in this report. Some of the lessons learned are presented with potential technical solutions, although some are items that must be considered during an operation involving the IWAA system. The report also makes a number of comments and recommendations on the supply chain for critical equipment to be used during emergency activities. The end of the supply chain for emergency operations is the disposal of wash water, earth fill, and spent vermiculite. The report makes additional observations and recommendations for this important, yet often overlooked topic.

Recommendations to enable deployment of the IWAA system technology during an emergency include:

- Developing tools to help work out logistical and regulatory questions specific to the deployment location of the IWAA system.
- Maintaining a stockpile quantity of suitable vermiculite.
- Creating a suitable separation skid for rapid deployment.
- Developing tools for responders to locate required equipment and supplies locally.
- Drafting a detailed protocol for reuse of wash water.
- Developing tools and scripts for responders to help coordinate wash water, earth fill, and vermiculite disposal with local authorities.

1. Introduction

The Irreversible Wash Aid Additive (IWAA) system has been under development by the U.S. Environmental Protection Agency (EPA) and Argonne National Laboratory (Argonne). The purpose of the IWAA system is, in the event of a radiological contamination event in an urban area, to restore functionality to critical infrastructure and public services, immediately reduce exposure of response personnel to radiation, and reduce the longer term consequences of the event. The process consists of three primary unit operations: wash down, followed by collection and filtration of resulting wash waters. The science underlying the wash-down operation requires a specific salt solution applied to contaminated surfaces (i.e., structures, roadways, and vehicles). This specific salt solution causes the radionuclides to be released from the surface. A sequestering agent then binds the radionuclides from the wash water and renders them environmentally immobile. As a result of laboratory studies using radioactive cesium-137 (Cs-137), the IWAA team was able to optimize the wash-down process and determine the removal efficiencies for Cs-137 from a variety of important material surfaces that may require mitigation to restore critical infrastructure and public services [1]. Radioactive cesium-137 was used to accurately account for adsorption sites on the contaminated materials, including sites that are present in insufficient amounts to be revealed by using non-radioactive cesium because detection limits for radioactive cesium are considerably lower than those of non-radioactive cesium.

To demonstrate the practical application of the unit operations, the IWAA team selected commercial off-the-shelf (COTS) technology for integration and demonstration at the pilot-scale level. This demonstration was held in Denver, Colorado, as part of the Urban Area Security Initiative (UASI) [2] in the U.S. Department of Homeland Security's (DHS's) Wide Area Recovery and Resiliency Program (WARRP) [3]. Separate reports summarize the literature review and experimental data from the development of the IWAA [1], as well as the selection of technologies that would potentially be integrated into this demonstration [4]. This selection of technologies led to small-scale demonstration experiments that prepared the team for the WARRP demonstration [5].

To finalize the logistics of the demonstration and logistics for receipt of materials and equipment in Denver, the IWAA team coordinated, consulted, and partnered with the Denver Fire Department, Denver Public Works, Denver Metro Wastewater Reclamation District, Denver Environmental Health, Cubic Applications, Inc., EPA, DHS Science and Technology Directorate, Battelle Memorial Institute, HESCO Global, Separmatic Systems, Mullarkey Associates, Darley Co., C&S Supply, Specialty Vermiculite Corp., and Briese and Associates.

The demonstration took place during the WARRP Capstone Event, September 13–14, 2012, at the Colorado Convention Center in Denver, Colorado. Some of the supply and equipment vendors also participated in the demonstration itself, including HESCO Global, Separmatic Systems, and C&S Supply. The demonstration consisted of setting up a rectangular perimeter of barriers ("berms") in a local parking lot. The purpose of the berms was to create an area where wash down could occur and also to form a "reservoir" to contain the wash-down water. The barriers were dual-compartment containers, and each compartment was filled by means of front loaders from a local heavy equipment supplier. The compartment nearest the inside of the bermed area was filled with the radionuclide (in this case, cesium) and sequestering agent (in this case, vermiculite clay). The side of this inner compartment was made of a water-permeable material, allowing contact of any cesium-contaminated water with the vermiculite. The outer compartment was filled with local fill dirt to conserve the clay and also to provide weight. The material used in the outer compartment was impermeable to water, which prevents leakage of contaminated water outside the berm. The area inside the berm (the floor of the reservoir) was covered with vermiculite clay by spreading the vermiculite using the same front loader. A 4 x 4 pickup truck meant to simulate a fire department command vehicle entered the bermed area via a ramp over the berm wall that was constructed from local fill dirt.

To apply the wash solution, the Denver Fire Department first placed an eductor unit with specifications chosen for the demonstration onto a fire hose equipped with a suitable spray nozzle. An eductor allowed the force of the flowing hydrant water to suction a secondary fluid into the main flow from the hydrant. Typically, such eductors are used to mix fire-fighting foam into water as it is sprayed. In this case, the purpose of the eductor was to mix the hydrant water with the salt solution necessary for radionuclide removal. The secondary fluid line for the eductor was placed into a salt solution contained in 55-gallon drums. (For the demonstration, the salt solution was simulated for logistical reasons.) In Figure 1, Denver firefighters are shown dousing the vehicle with a simulated wash aid.

Figure 1. Dousing of vehicle with wash aid solution in IWWA demonstration (Denver, Colorado, September 14, 2012).

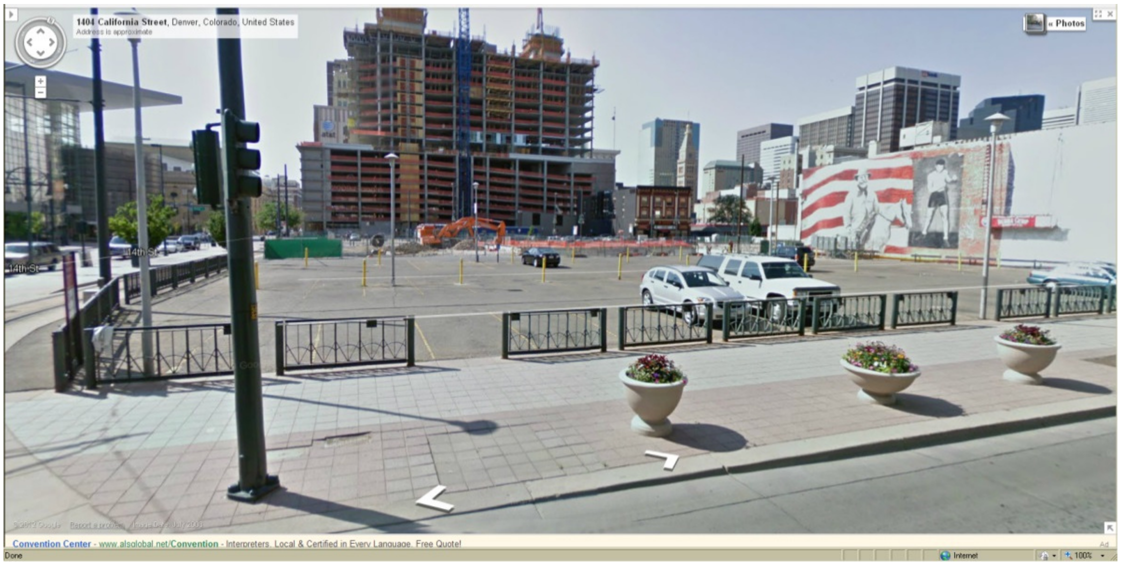
Once "clean", the vehicle was driven out of the reservoir. Because this operation did not produce sufficient water to demonstrate the operation of the filtration system and the containment capabilities of the berm, the firefighters continued to fill the berm with simulated wash aid solution to a depth of approximately 1 foot. The resulting slurry was purified by a mobile filtration system. The pumps of the filtration system can push 50–70 gallons per minute (gpm) through a combination of centrifugal and mechanical filters designed to allow (1) the vermiculite to be collected efficiently in radioactive waste containers and (2) the filtration system to be operated for extended periods without clogging or reducing the filtration efficiency. Because the demonstration did not utilize radionuclides, the solid and liquid wastes from the filtration system were merely collected in a public works suction truck for storage prior to disposal. The filtration system was run for approximately 10 minutes to demonstrate the wash and filtration system to the observers.

Removal of the reservoir was the next step in the demonstration. With all the slurry and solution removed from the reservoir, the demonstration showed how the container materials comprising the berm can be separated from the fill material for disposal. After the connector pins between the containers were extracted, a front loader lifted the container units, allowing the fill material to fall out. (For the demonstration, the container bottoms were open; in actual deployment, the container bottoms would be an impermeable material. Should the containers contain radioactive material, the container can be placed on a truck and hauled away.) The front loader then collapsed the containers accordion-style, and the containers were loaded into a truck for disposal or reuse. The emptied fill material was removed by a front loader into a covered truck for disposal. A Denver street sweeper then completed cleanup.

2. Purpose of the Demonstration

The purpose of the Denver demonstration was to assemble an IWAA system and demonstrate its primary unit operations. For the demonstration, no radioactive material was used. The IWAA system for radioactive cesium mitigation consists of a solution to wash down contaminated structures, roadways, and vehicles, as well as a sequestering agent to bind the radionuclides from the wash water and render them environmentally immobile. The sequestering agent also facilitates separation of the radionuclides from the bulk water for transport and disposal and possible reuse of the water. The wash solution is designed to be disseminated easily by first responders using water sources, eductors, and nozzles already used by firefighters to distribute foaming agents.

The initial concept was to demonstrate the wash down of a building façade. However, based on the need to conduct the demonstration in the vicinity of the Colorado Convention Center, site of the DHS WARRP Capstone Event, the team decided to demonstrate the process on a command-style vehicle (a pickup truck such as the RAM 1500 and Ford F150 models) commonly used in emergency response. Vehicle washing is a realistic need in response to a radiological incident, not just during the emergency phase, but throughout the restoration and recovery process. The final site for the demonstration was chosen based on proximity to the Convention Center, where poster and oral presentations were being held as part of the WARRP Capstone Event. The requirements for the site included: sufficient open space to accommodate the berm around the vehicle and space to maneuver the front loader, fire truck, and vacuum truck; minimal disruption of traffic; and availability of a water supply. The parking lot across from the Convention Center (Fig. 2) was the best option, so the EPA secured the rental of the parking lot for the demonstration.



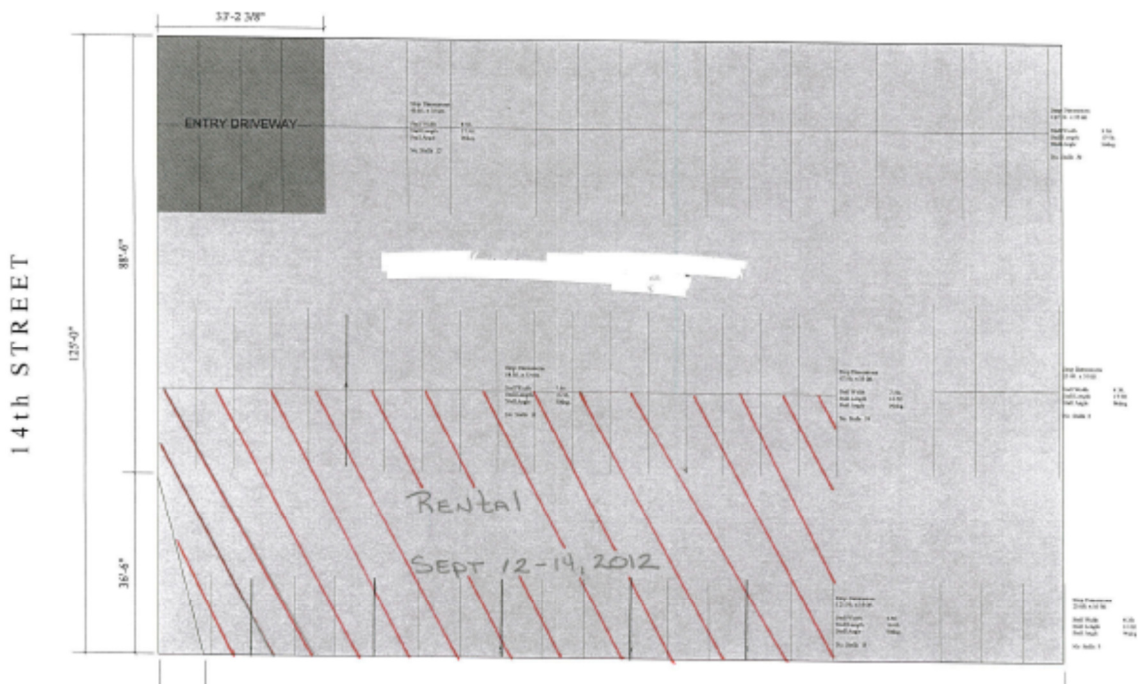


Figure 2. Site of IWAA demonstration at 1417 California St. in Denver. The top view looks north-northwest from California St. To the left, 14th St. is visible. The overhead view (bottom) of the parking lot shows the rental spaces.

3. Narrative Description of the Demonstration

Following is a summary of the demonstration. Details like part numbers and supplier contact information are found in Section 6, "List of Equipment and Costs."

3.1 Setup of the IWAA System

The demonstration consisted of setting up a rectangular berm in a local parking lot. The purpose of the berm was to create an area where wash down could occur and also to form a "reservoir" to contain the wash-down water. The berm was formed from dual-compartment containers, and each compartment was filled by use of front loaders from a local heavy equipment supplier. The containers were COTS products that are frequently filled with sand or earth and deployed for flood control and protection of military personnel. The containers are shipped in a collapsed state to the site of use, and when they are no longer needed, they can easily be emptied and collapsed for storage or disposal. The containers used for the demonstration were manufactured by HESCO Global. The containers are available in a variety of materials.

The containers were chosen due to their off-the-shelf nature coupled with their ability to be deployed rapidly as a barrier at an operationally relevant scale. The compartment nearest the inside of the bermed area was filled with the radionuclide (in this case, cesium) and a sequestering agent (in this case, a particular vermiculite clay). The side of the inner compartment was made of a water-permeable material, allowing contact of any cesium-contaminated water with the vermiculite. The outer compartment was filled with local fill dirt to conserve the clay and also to provide weight. The material used in the outer compartment was impermeable to water to prevent leakage of contaminated water outside the bermed area.

The area inside the berms was then covered with vermiculite clay by spreading it using the same front loader. The 4 x 4 pickup truck simulating a fire department command vehicle entered the bermed area via a ramp constructed of local fill dirt over the berm wall.

3.2 Wash Aid Application

To apply the wash solution, the Denver Fire Department first placed an eductor unit with specifications chosen for the demonstration onto a fire hose equipped with a suitable spray nozzle. The eductor allows the force of the flowing hydrant water to suction a secondary fluid into the flow, permitting the application of an additive to the water. Typically, such eductors are used to mix fire-fighting foam with water as it is sprayed. For the demonstration, the purpose of the eductor was to mix the hydrant water with the salt solution necessary for radionuclide removal. The secondary fluid line for the eductor was placed into a salt solution contained in 55-gallon drums. (For the demonstration, the salt solution was simulated for logistical and practical reasons.) The firefighters doused the vehicle in the simulated wash aid solution.

3.3 Wastewater Collection

In an actual incident, the water running off the pickup truck, which would contain radioactive elements, would mix directly with the vermiculite clay spread over the bottom of the bermed area, where the radionuclides would bind to the clay surface. Additional binding may occur via the vermiculite in the inner compartment of the containers, which comprise the berm. For the demonstration and an actual incident, all the wastewater is contained within the bermed area. The water and clay form a slurry, which collects in the reservoir. The slurry can be withdrawn by using suction pumps and piped to the separation system.

3.4 Separation of [Radioactive] Solids

The separation system is designed to quickly separate the solid clay containing the concentrated radionuclides, in an actual deployment, from the relatively clean wash water. The separation system consists of centrifugal and fabric filters contained on a mobile trailer. The centrifugal filter step, during actual operation, might consist of several centrifugal filters connected in series depending on the solids loading. It is designed to remove >90% of the solids before sending the effluent to the fabric filters. The fabric filter tank serves as a settling tank for the fabric filter to remove the remaining radioactive solids. The solid material from both types of filters is pumped into holding vessels (e.g., bladder tanks or tanker trucks, whatever is available and of suitable volume). The filtered water can be pumped into a bladder tank, tanker truck, or another reservoir for on-site treatment to reduce salt concentration or for reuse, if needed. The treated effluent can then potentially be discharged to the sewer system (with concurrence of the relevant regulatory authorities). The bladder tanks or tanker trucks can be transported to another location for additional waste treatment and disposal.

Once "cleaned" by application of the separation system, the demonstration vehicle was driven out of the reservoir. Since this operation did not produce sufficient water to demonstrate the operation of the filtration system and the containment capability of the bermed area, the firefighters continued to fill the berm with simulated wash aid solution to a depth of approximately 1 foot. The resulting slurry was purified by a mobile filtration system. The pumps of the filtration system push 50–70 gpm through a combination of centrifugal and mechanical filters designed to allow (1) the vermiculite to be collected efficiently in radioactive waste containers and (2) the filtration system to operate for extended periods without clogging or reduced filtration efficiency. Because the demonstration did not utilize radionuclides, the solids and the liquid waste from the filtration system were merely collected in a public works suction truck for storage prior to disposal. The filtration system was operated for approximately 10 minutes to demonstrate the wash and filtration systems to the observers.

3.5 Teardown of the IWAA System

Immediately after the washing of the vehicle, the barrier system remains. The barriers are designed to be lifted intact by bulldozers or front loaders and placed in trucks for transport. Alternatively, the individual containers alone can be disconnected from the berm, and the detached containers then can be removed, consolidated, and hauled away for reuse or management as waste. This arrangement allows the earthen fill material to be collected and hauled away and managed separately.

With all the slurry and solution removed from the reservoir, the demonstration showed how the container materials comprising the berm can be separated from the fill material for disposal. After the connector pins between the containers were extracted, a front loader could lift the container units, allowing the fill material to fall out. (For the demonstration, the container bottoms were open; in actual deployment, the container bottoms would be an impermeable material. Should the containers contain radioactive material, the container can be placed on a truck and hauled away.) The front loader then collapsed the containers accordion-style, which were loaded into a truck for disposal or reuse. A Denver street sweeper cleaned up the parking lot of any remaining vermiculite and dirt, returning the parking lot to its predemonstration condition, perhaps even cleaner.

3.6 Overall Summary of Demonstration

This activity successfully demonstrated, on a practical scale, the primary unit operations for building a containment structure for radioactive wash waters—washing down a hypothetically radioactively contaminated vehicle, collecting the hypothetically radioactive slurry waste water, filtering the radioactive wash waters, disassembling the containment, and transporting the waste materials for disposition. In addition, the demonstration provided an opportunity to examine the supply chain for critical materials.

4. Step-wise Activities in the Demonstration

The demonstration included all steps that would be used when deploying the IWAA system for the purpose of decontaminating vehicles. Other applications are possible, due to the flexibility of the dual-compartment container system, which allows bermed areas to be potentially deployed around a large number of assets that would be important to decontaminate following an actual radionuclide release. Specifically, the demonstration in Denver consisted of the following stepwise activities:

1) Creating a temporary reservoir using berms consisting of HESCO dual-compartment containers. The reservoir's inner perimeter had dimensions of 18 ft by 30 ft.
2) Filling the outer compartment of the HESCO container with fill dirt from a local source and the inner compartment with vermiculite clay.
3) Spreading the remaining vermiculite clay across the reservoir surface (in a real incident, this vermiculite layer would be used to capture radioactive cesium washed from the vehicle).
4) Constructing a ramp to permit entrance and egress of the test vehicle.
5) Filling three 55-gallon drums with water to simulate the tanks of potassium-based salt brine used to promote the release of radioactive cesium from surfaces. The wash aid solution consists of 0.5 M K^+ or NH_4^+ as the chloride salt (or other available potassium or ammonium salt) with a surfactant additive (1 mM sodium dodecyl sulfate) to improve the wettability of asphalt and other hydrophobic surfaces.
6) Connecting the 6% proportioning nozzle and eductor to the Denver Fire Department fire hose and Y-connecting to the brine tanks.
7) Washing the test vehicle with the simulated 6% brine solution.
8) Removing the decontaminated test vehicle from the reservoir.

9) Removing the slurry through the LAKOS centrifugal filter with final clarification in the Separmatic filter pressurized cartridge filter unit at 50–70 gpm to demonstrate its function.

10) Discharging filtered water into the municipal vacuum truck for disposal according to Denver regulations. This process simulated discharging the filtered water into a secondary tank for on-site or off-site treatment to reduce salt or surfactant concentration according to regulations. It must be emphasized that management of the filtered rinse water must be done in accordance with relevant permitting authorities.

11) Capturing purge contents from the LAKOS centrifugal filter into the bag filter to simulate pumping into an approved low-level radioactive waste (LLRW) bladder tank for transport, treatment, and disposal.

12) Capturing the purge contents from the Separmatic filter units into a vacuum truck to simulate pumping into an LLRW bladder tank for transport, treatment, and disposal.

13) With the separations demonstration complete, removing the remainder of the water from the reservoir for disposal by using a municipal vacuum truck according to Denver regulations. Note that this step is an artifact of this operation being a demonstration; in the case of a real radiological incident, this step would not be performed.

14) Removing berm liners and containers. In the case of a real radiological incident, the berm liners and containers might be reused or managed as radioactive waste.

15) Removing hypothetically contaminated clay and fill dirt by shoveling and lifting material into a municipal dump truck using the front loader. In the case of a real radiological incident, the clay and fill dirt would need to be managed as radioactive waste.

5. Photos and Video of the Demonstration

Below is a set of photos (Figs. 3–23) documenting the different operations during the demonstration. A local television station, KDVR, videotaped the demonstration as well. The EPA obtained the high resolution footage and created a video of the demonstration. To play, click on the inserted object below. Some versions of Word will not play the video, so it is also included in the zip file that contains the present document.

Irreversible Wash Aid Additive - WARRP demonstration.wmv

Figure 3. The HESCO Concertainers® being packaged accordion-style and shipped on a pallet to the site.

Figure 4. The fill dirt being delivered by a dump truck to the corner of the parking lot. A small front loader was used to move the fill material. In an emergency, the fill for the barriers can be obtained from any local source.

Figure 5. The vermiculite clay being shipped as 3000 lb totes that were lifted by a front loader and cut open using box cutters. At least 20–30 tons of the vermiculite can be shipped from domestic sources upon request.

Figure 6. The HESCO dual containers being connected to each other using long steel pins that run concurrently through the ringed corners of the bags. An inner partition (the green wall) bisects the containers and is held in place using the same steel pins.

Figure 7. A worker inserting a galvanized steel pin into the adjoining rings on the partitions and baskets to secure a partition in place.

Figure 8. The HESCO containers being joined by workers with little prior training. The HESCO in-field representative explained the procedure in less than five minutes to scientific staff and Denver municipal staff.

Figure 9. A contractor filling the exterior compartment of the HESCO containers with fill dirt using the front loader.

Figure 10. Vermiculite clay being dumped within the footprint of the reservoir created by the HESCO containers to sequester the "radioactive cesium" that was washed from the vehicle. Use of this vermiculite layer prevents any seepage waters from contaminating the surrounding areas.

Figure 11. The inner compartment being filled with vermiculite clay to serve as a sequestering barrier to "radioactive" seepage. This operation was performed after the outer compartment was filled.

Figure 12. HESCO dual compartment containers showing the outer fill dirt (left side, impermeable to water) and inner vermiculite clay (right side, permeable to water). The fill dirt located to the left of the containers is part of the ramp constructed to permit entrance and egress of the vehicle.

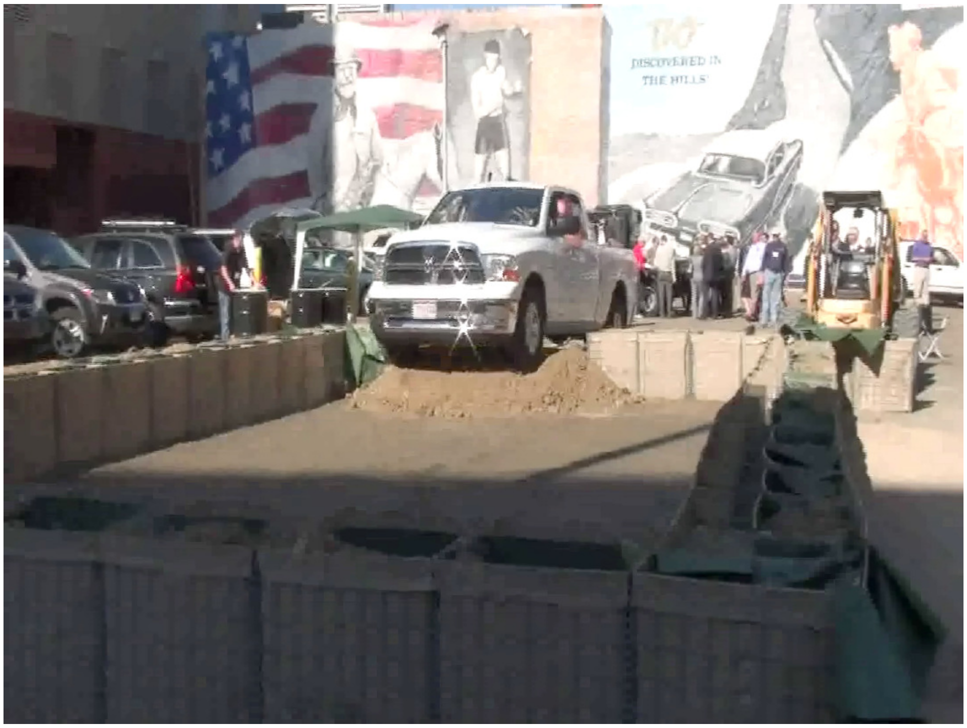


Figure 13. Test vehicle being driven into the reservoir for "decontamination" after the berms had been filled and ramp completed.

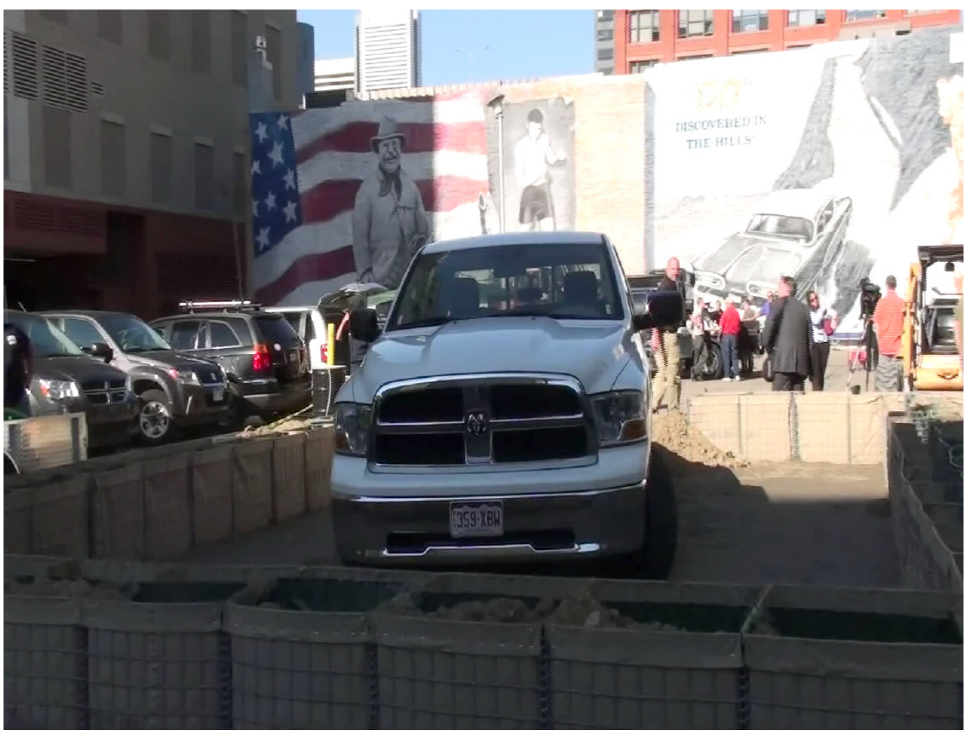


Figure 14. The vehicle after having been placed in the middle of the reservoir to minimize overspray from the fire hose.

Figure 15. Firefighters washing down the vehicle with the simulated 6% brine solution. Laboratory tests suggest that this brine solution will remove >98% of the radioactivity from the vehicle's painted surfaces. Note the vehicle ramp on which the firefighters are standing.

Figure 16. Firefighters filling the reservoir with water to simulate an operation that would use thousands of gallons of radioactively contaminated water. Once "decontaminated," the vehicle was driven out of the reservoir. Note the black 55-gallon drums that contained (simulated) brine/surfactant behind the firefighters, where the concentrated brine and surfactant would have been prepared.

Figure 17. View of the dirt ramp and reservoir filled with water before the start of slurry separations.

Figure 18. Another view of the reservoir shortly after the start of slurry separations. Notice the lack of seepage water surrounding the berms. Only one location showed a small volume of water that appeared to be seeping from under the berms.

Figure 19. Green intake hose drawing "contaminated" slurry from the reservoir into the separator units mounted on the mobile filter skid.

Figure 20. (Top) View of reservoir during simulated decontamination process. The mobile filter skid is at the rear of the bermed reservoir. Note the green intake hose held at the corner of the reservoir, which passes the slurry through the LAKOS centrifugal separator (the small blue dumbbell unit in the front of the skid). The effluent of the LAKOS unit enters the Separmatic Systems' pressurized filter unit, which is the slender, stainless steel vertical tank behind the LAKOS unit. (Bottom) The mobile filter skid.

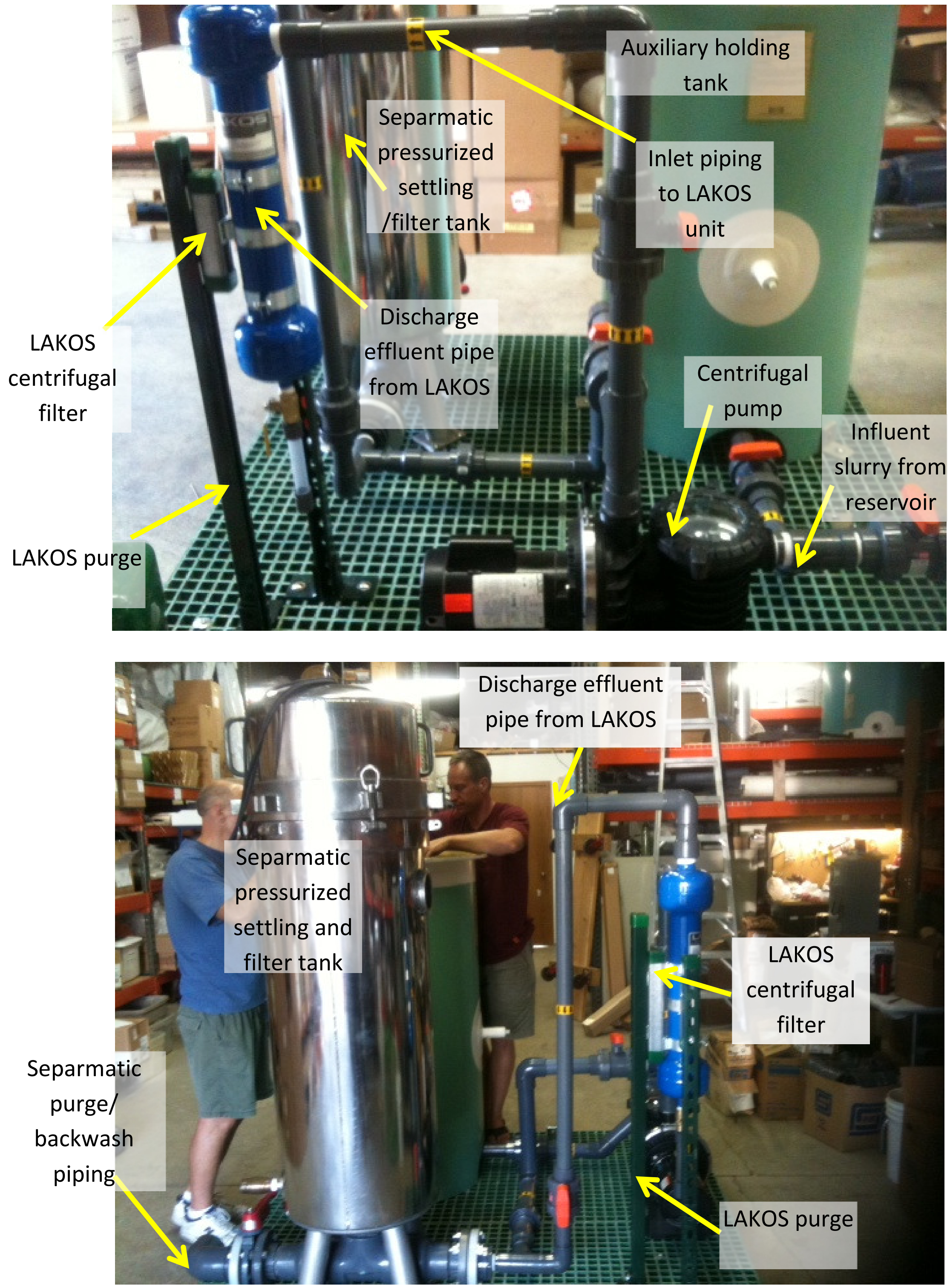


Figure 21. Closer views of the 50-gpm mobile filter skid containing the LAKOS and Separmatic filter units connected in series. The bottom picture is viewed from the front and the top picture is viewed from the back. The blue dumbbell unit is the LAKOS centrifugal separator, the green tank is the auxiliary holding tank (if needed), and the stainless steel tank is the pressurized settling/filter tank for final clarification.

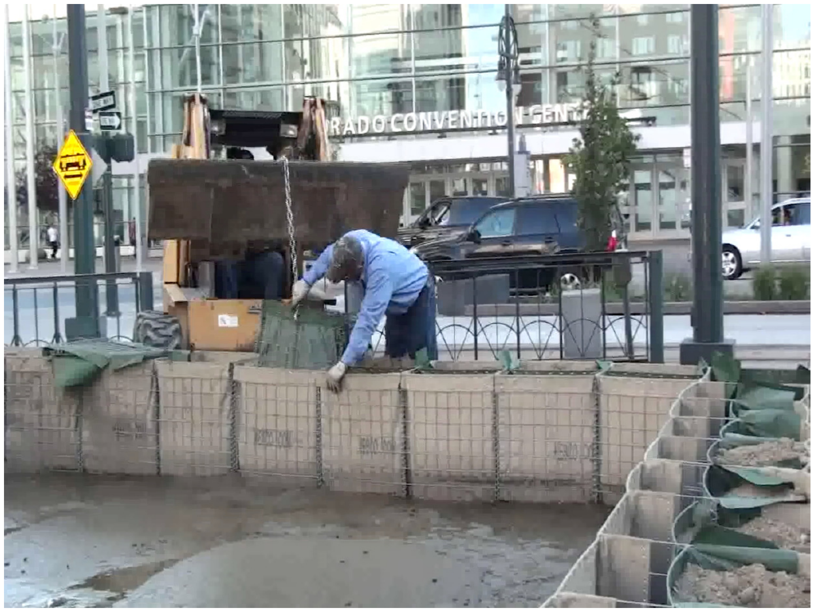


Figure 22. Containers being removed after water was removed from reservoir. At a radioactively contaminated site, the HESCO containers can have a liner underneath so the entire contents can be wrapped like a diaper and lifted whole, using a front loader or similar machine and placed intact into a transport vehicle for treatment and disposal at an external facility. For the demonstration, the pins that held the partitions were removed manually, and the containers were then lifted out using the front loader equipped with hooks and chains.

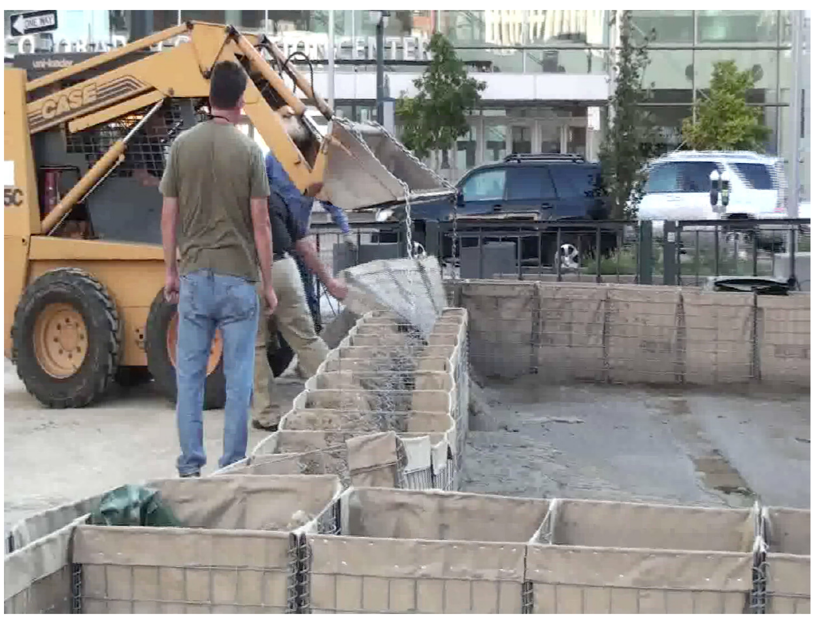


Figure 23. Containers being lifted in the same manner as the partitions, leaving the clay and earth fill in place. The containers were collapsed and hauled away for reuse at another location. The clay and fill were then shoveled into a dump truck using the front loader and were hauled away to a local landfill.

6. List of Equipment and Costs

Table 1 summarizes equipment and supplies, along with suppliers, utilized in the IWAA system. As the actual quantities and corresponding costs would depend on the actual deployment context, the actual quantities and corresponding costs are not listed in the table, but some of this information is contained in the text below. Table 1 contains some brief notes that are expanded upon in the text.

Table 1. Listing of supplies and equipment for IWAA system. Some supplies and notes are also included.

Item	Supplier	Notes
Barrier materials (Concertainers®)	HESCO Global	Dual compartment containers, impermeable on the outside and permeable on side facing wash water.
Brine tanks	Local	Any container in which salt and surfactant can be mixed.
Earth fill	Local	For weight in the barriers.
Eductors, nozzles, and hoses	Darley Company with C&S Supply Company	Threading should match local fire equipment.
Fire engine	Local	In the demonstration, the city of Denver provided the engine and firefighters.
Front loader and dump truck	Local	Local companies or agencies can supply equipment and operators.
Salt	Local	Potassium chloride is used as a water softener salt. Ammonium salts are available in ton quantities.
Separation system	Separmatic Systems	Separmatic Systems combined their units with the LAKOS filter from Mullarkey and Associates, Inc.
Surfactant	Local	Also known as sodium lauryl sulfate.
Vermiculite	Specialty Vermiculite Corp.	Item # VCX 205 was tested for cesium-137 in the laboratory. Performance for other vermiculites is unverified.
Waste disposal (solid and liquid)	Depends on level of radioactivity	In demonstration, the city of Denver disposed of waste because it was nonradioactive.

6.1 Demonstration Location

Approximately 32 parking spaces were rented in the parking lot across from the Colorado Convention Center (the site of the WARRP Capstone meeting) from Focus Parking, (303) 296–7550. The EPA was able to cover the costs for this rental, because the space was used for operational demonstrations of other WARRP projects as well as this one.

6.2 Vermiculite

Specialty Vermiculite Corp. (formerly Grace Co.) supplied the vermiculite ore concentrate (VCX 205). They can supply 50 lb bags, 3000 lb totes, or 1 ton bulk (21 tons Less Container Load and 95 tons by rail at $131 per ton). Three totes were purchased at a unit price of $267.02 per tote for a total of $801.06.

The vermiculite was shipped through a commercial freight company (Sparta Logistics) at a cost of $3,489.56, which included the forklift to unload the material. (The detailed price sheet is provided in the Appendix).

6.3 Salt and Surfactant

Prices for salt and surfactant are estimated in Section 7.5.2. Due to the small volumes of salt required for this demonstration, 40 lb bags of potassium chloride could have been purchased from a number of local suppliers. Potassium chloride is used as an alternative to sodium chloride in domestic water softeners. For the demonstration, potassium salt was not used because the only value of using salt would have been to trivially demonstrate that it is possible to dissolve salt into water in a 55-gallon barrel. Further, not including salt prevented the possibility of accidental overspray of observers with salt solution, which would have resulted in salt residue on the observers' clothing. No overspray was observed. In addition, not including salt made it simpler for the Denver Department of Public Works to dispose of water exiting the mobile filtration system into the sewer system because it was unclear if introducing salt solutions into the nearby sewer system would have violated any municipal regulations. Certainly, salt solutions used for snow removal routinely enter such storm drains as an unintended consequence of their use, but the demonstration could have been construed as being an intentional introduction. Rather than explore this legal and/or permit issue, it was simpler to avoid the use of salt. Before using the salt solution during an actual emergency, local authorities should be consulted.

Sodium dodecyl sulfate (SDS) is a surfactant additive to improve the wettability of asphalt and other hydrophobic surfaces. SDS has several synonyms, with sodium lauryl sulfate being commonly used (Chemical Abstract Services Registry number 151-21-3). SDS is available from local chemical suppliers and cleaning companies, and is present in a variety of household products, some of which are listed in the Household Products Database [6]. For a demonstration this size, SDS can be purchased via laboratory supply companies, but SDS was excluded from the demonstration because, like the potassium chloride, the use of actual SDS would have had trivial benefit for the demonstration, and avoiding the use of SDS avoided the same issues as discussed above for potassium chloride. The cost saving of not including the salt and surfactant in the demonstration was comparatively trivial.

6.4 Barrier Materials

The barrier materials were dual-compartment barrier containers (Concertainer® units by HESCO Global). These 2-ft x 2-ft x 2-ft baskets have a permeable outer geotextile and impermeable inner partition, creating 1-ft deep compartments. The individual Concertainer® units are shipped accordion-style and expanded on-site. The cost of these containers for a large-scale deployment is estimated at about $20/linear foot.

6.5 Earth Fill, Front Loader, Dump Truck, and Operator
The dirt used to fill the outer compartment of the HESCO containers, the front loader used to haul materials and fill the HESCO containers, the dump truck, and the certified equipment operator were provided by ET Technologies (Parker, CO) at a cost of $965.00 (see Appendix for detailed quote).

6.6 Brine Tanks
The three 55-gallon drums used to simulate the brine tanks containing saturated potassium or ammonium salt solutions were provided by Denver Environmental Health at no cost to the program. Such drums retail for approximately $100 each. Any container suitable for mixing solid salts with water could have been used. Other options are presented in Section 7.5.5.

6.7 Fire Engine and Firefighters
The Denver Fire Department provided four firefighters and an on-duty engine pump truck at no cost to the program.

6.8 Eductor, Nozzles, and Hoses
Collaboration with the Darley Company, C&S Supply Co., Briese and Associates, and the Denver Fire Department resulted in determining the type of eductor and nozzle that would work best for this demonstration. The Denver Fire Department uses National Standard Thread (NST) on their equipment. A 30 gpm eductor and nozzle (Fig. 24) were deemed sufficient and could provide the 6% concentration of the secondary fluid (the wash aid concentrate) out of the nozzle, which would allow the use of the target concentration of 0.5 M potassium salt from the concentrated brine. The list of parts (below) has a total price of $1,232.80 (the detailed price sheet is provided in the Appendix).

- 1.5 in., 30 gpm eductor with 20 ft pickup line (BYPP15501.5-60-DUAL 20 FT)
- 1 in. nozzle, 30 gpm nozzle (AM080)
- 1.5 in. x 1 in. valve (VB15/10)
- 2.5 in. x 1.5 in. Gated Wye (AM078)
- 1.5 in. yellow hose (U273)

Figure 24. The 1 in., 30 gpm nozzle (Part # AM080) pictured on the left connects onto the 1 in., 30 gpm eductor (Viper BYPP Foam Eductors) pictured on the right.

6.9 Separation Systems

The LAKOS unit (1½ in., 45–70 gpm MPT LAKOS Separator) was purchased from Mullarkey and Associates, Inc. (Tinley Park, IL). Mullarkey and Associates, Inc. consulted on the size and type of LAKOS separator for the demonstration. They shipped the unit with a ¾ in. manual/visual purge and mounting bracket to Separmatic Systems. The LAKOS system cost $596.50 (see Appendix for quote sheet).

Separmatic Systems was contracted to integrate the LAKOS unit as the primary filter and the Separmatic pressurized bag filter as the final clarifier. Much of this work was completed with in-kind effort by Separmatic. The final integrated mobile skid system and contract costs, including effort and travel, totaled $12,000 (see Appendix for quote sheet).

6.10 Wash Water, Earth Fill, and Vermiculite Disposal

The filtered wash water from the mobile filter skid and the remaining water within the reservoir were vacuumed by the Denver Department of Public Works and discharged to a sanitary manhole, with approval from Denver Environmental Quality and Denver Metro Wastewater Reclamation District, at no cost to the program. The earth fill and vermiculite were hauled for disposal by ET Technologies for the bulk cost quoted above. They were disposed of at a local landfill by Denver waste management, at no cost to the program.

7. Conclusions and Lessons Learned

Completion of the demonstration occurred without complication. The materials arrived as planned, and the various partners were well-coordinated. The IWAA team demonstrated the setup of the system and its operation on a practical scale. The team also assessed the additional operations required for removal of materials and cleanup of the site. From this experience, several logistical and regulatory questions were prepared, applicable to deployment of the IWAA system in the future:

Logistical Questions

- How do you coordinate and train the individuals needed to transport the berms and fill materials and assemble them in a hazardous and radiation area?
- Where exactly do you set up the berms and how much water is needed to accomplish the mitigation goal?
- Given the limited footprint in the affected zone, where do you assemble the support equipment (salt and surfactant storage, pumps, filtration trucks, front loaders, bladder tanks, collapsible tanks, fire trucks, etc.)?
- Depending on the location of such tanking, do you have the means of piping the materials to and from these tanks (e.g., are the tanks close enough to the fire truck to permit drafting the contents of the brine/surfactant tank into the fire hose without auxiliary pumps)?

Regulatory Questions

- Do you permit units to set up in a radioactively-contaminated zone or do you wash the staging area first and then proceed with mitigation operations at the target zone?
- How do you construct a system to facilitate the reuse of wash water at a particular site?
- What type of system would need to be included to monitor the water quality before reuse to ensure the absence of radioactivity?

The technical lessons learned from the demonstration are discussed in the sections below.

7.1 The Reservoir

For this demonstration, constructing the reservoir using the HESCO Concertainers® was straightforward and required only a couple of minutes of instruction from the HESCO technical representative. However, it was not clear what procedures must be instituted for work in a radiological contamination zone. The HESCO representative stated that they have well-trained personnel who routinely perform cleanup in hazardous areas, and these personnel are well trained in safe operation under those conditions, but radiological conditions will require additional considerations.

The volume of permeate observed around the reservoir was very low (Figure 18), with the asphalt pavement appearing damp in only one spot. Some of the berms were purposely set up to span an uneven trench across the parking lot to determine whether the berms would conform to the uneven geometry and prevent the leakage of water. The lack of permeate is a very good outcome because it shows that the HESCO Concertainers® are pliable enough to conform to relatively minor imperfections in the surface on which they are installed, suggesting the efficacy of using available earth to fill the berms instead of prescribing vermiculite. This substitution would save costs and eliminate a delay in supplying berm-filling material to start wash-down activities.

7.2 Separations

Since the slurry composed of the vermiculite and the water in the reservoir was not well mixed, slurry intake was not controlled, leading to highly variable solids concentrations at the inlet to the LAKOS separator. This variation in solids content made manually controlling the LAKOS purge valve very difficult. As a result, the solids concentration was too high in the discharge from the LAKOS (the feed into the Separmatic pressurized bag filter unit). The high concentration of solids led to a premature pressure drop across the Separmatic filter, signifying a need to backwash the Separmatic filter well before the expected duration.

Evidently, extremely high slurry concentrations can make a single LAKOS unit inefficient, falling well short of the expected solids separation factors (expected to be ~90% solids removed). Under such conditions, a series of LAKOS units would be necessary. Another option is to consider leaving the clay in the reservoir because the clay settles readily by gravity, and the supernatant wash can simply be pulled into the filtration units, or the wash water can be collected in a series of drain tiles. Then, after drawing out most of the water (dry contaminated clay particles could be spread by the wind), the concentrated slurry could be suctioned into a receiving truck for removal.

7.3 Comments/Recommendations on the Supply Chain for Critical Equipment and Supplies for Use of the IWAA System during Emergency Response

Coordinating the receipt of a variety of reagents for a pilot-scale demonstration afforded the opportunity to survey the supply chain. As part of the lessons learned, here are comments on the supply chains of the critical reagents.

7.3.1 Vermiculite

Moderate quantities of vermiculite (~30 tons) are available immediately for shipment by Specialty Vermiculite (formerly Grace Co.) from domestic mines. Larger supplies would require more than several days. Specialty Vermiculite offers four grades of the ore concentrate: Medium (VCX 203), Fine (VCX 204), Superfine (VCX 294), and Micron (VCX 205), with size ranges as shown in Table 2. Other suppliers are available but different types of vermiculites may have different sorption properties that can significantly affect its performance in sequestering radioactive cesium in the IWAA process.

It may be desirable and comparatively inexpensive to maintain a stockpile of a quantity of suitable vermiculite and/or to investigate other solutions for the supply of vermiculite. These solutions involve further minimizing its use and identifying additional suppliers of vermiculite that has similar properties.

Table 2. Typical particle sizes for VCX vermiculite concentrate (cumulative % weight retained).

U.S. Screens	Particle Size (mm)	Vermiculite Grade (wt % retained)			
		VCX 203	VCX 204	VCX 294	VCX 205
8	2.38	0–2.0			
20	0.84		0–2.0		
30	0.59	85.0–93.0	0–15.0	1.0–10.0	0–1
50	0.297				0–20
70	0.21	95.0–100.0	85.0–95.0		
100	0.149		90.0–100.0	45.0–100.0	30–76

7.3.2 Salt and Surfactant

For this size demonstration, potassium salt can be purchased as 40 lb bags from a number of local suppliers. Prices vary with the potassium commodity market; currently, the price is approximately $0.60/lb. Supply of bulk quantities would not be limited by region. Several companies can supply potassium salts from existing stockpiles and shipments in the range of thousands of tons are routine. Ammonium salts are also available in bulk and are routinely distributed in quantities greater than hundreds of tons. Often, ammonium salts are available in the form of ammonium nitrate, and disposal of nitrate salts in sanitary sewers and/or stormwater systems may increase nutrient loading downstream, which may be of concern for wastewater authorities. Wastewater authorities should be consulted [7], although nutrient loading concerns may be secondary to radioactive contamination in an emergency.

The surfactant SDS, which is used to improve the wettability of the wash aid solution onto hydrophobic surfaces like asphalt, can be purchased via laboratory supply companies for a demonstration of this size. Bulk quantities are supplied in acidic form as a pure solid or in the neutralized sodium form as a liquid at concentrations up to 40% and are distributed by rail or tanker. The bulk product is routinely shipped by rail car (200,000 lb) or tanker truck (40–45,000 lb) as the acid or neutralized form. Prices in bulk are ~$1/lb in acidic form and $0.60/lb in neutralized form.

7.3.3 Barrier Materials

HESCO Concertainers® are designed for deployment under emergency operations with very short turnaround times, and are commonly used to build temporary containment for periodic flooding episodes. As described in [1], other vendors can supply barrier systems that may be appropriate for some situations, although the other barrier systems must be capable of achieving the same technical goals for the barrier system described above, particularly in terms of permeability and tolerance to surface imperfections in the assembled product. Arrangements should be worked out in advance to enable procurement of suitable barrier systems for radiological incidents.

7.3.4 Earth Fill, Front Loader, Dump Truck, and Operator

Earth materials (i.e., sand, dirt, clay, or stone) to fill the berms would be readily available locally as would the earth-moving equipment (loaders, trucks, excavators, tractors, etc.) needed in an emergency situation through the Emergency Resource Guide for the area. Operators of these vehicles and equipment may require specific training for work in a radiological environment.

7.3.5 Brine Tank

Brine tanks of sufficient size can be obtained from local fire departments or hazardous materials teams, or from the Emergency Resource Guide for the area. Extremely large tanks (in excess of 10,000 gallons) may require establishing a reservoir using the barrier materials demonstrated in this report.

7.3.6 Fire Engine and Firefighter

Water pumping trucks and firefighter operators to educt and disseminate the wash aid additive solution are common resources for local fire departments. Water pumping trucks and firefighter operators are also listed in an area's Emergency Resource Guide.

7.3.7 Eductors, Nozzles, and Hoses

Eductors, nozzles, and hoses are common equipment for local fire houses. However, many eductors produce a maximum outflow of 3% of the concentration of the secondary fluid (3 parts secondary fluid or wash aid additive to 100 parts hydrant water). Approximately a 6% concentration is expected to be required to be effective. It needs to be determined if such eductors are common inventory items.

7.3.8 Separation Systems

The separation skid utilized for the demonstration was of suitable size for operations involving vehicle washing. However, for larger areas, Mullarkey Associates said that the largest separators are not generally kept on the shelf but can be manufactured quickly. A 650 gpm separator (~10 times the size in the demonstration) may require a few days to deliver (particularly into a radiologically impacted area), although some support equipment may be less available and contribute to deployment delays. Supporting equipment includes a solids-rated centrifugal pump, suction pumps of the size needed to pump 650 gpm, the connections, the skid platform, etc.

Because of the various required components, assembly of a large skid that can be moved across the country is recommended. The size of the skid would need to be decided on by consensus among potential users. Other possibilities and options could be explored. For instance, many of the larger components are currently installed around the country in various routine applications. The manufacturer reported that these assets have occasionally been diverted to urgent applications, although not yet necessarily to emergencies.

7.4 Wash Water, Earth Fill, and Vermiculite Disposal

The disposal of "treated" water and potentially radioactively contaminated waters and solids will require special attention and may be subject to modified regulations for emergency situations. Under existing normal regulations, these materials may need to be captured and treated or disposed as low-level radioactive waste. It is critical to discuss management of potential waste streams that may be generated from the use of this wash aid technology with relevant permitting authorities. The relevant permitting agencies may include, but are not limited to, local, state, and federal regulatory authorities for solid waste and wastewater. Accordingly, the Water

Environment Research Foundation (WERF), in partnership with the EPA, hosted an expert workshop to engage with subject matter experts and wastewater utility stakeholders on a number of topics surrounding radionuclides in wastewater collection and treatment systems, should the radionuclides enter the systems as a result of an emergency situation [7].

Some topics that may come up in this discussion with wastewater authorities include 1) whether the wastewater authority wants additional sample analysis of the spent wash aid additive and 2) whether, for the particular wastewater system affected, the spent wash aid solution requires treatment to reduce the salt concentrations to allow ready disposal. Because the wash aid additive was processed with vermiculite clay in the separation system, the spent wash aid additive solution should technically be free of radionuclides, but there may be nontechnical reasons why the wastewater authority wants additional sampling, e.g., for assurance of the public. Also, the need for treatment of spent wash aid solution may be related to the exact volume discharged. Sanitation sewers may be able to handle salty water if the load (volume and concentration) is below certain limits. If this load is too high, then on-site pretreatment of the wash water may be necessary before discharge. On-site treatment methods for salt reduction are being pursued as part of the ongoing efforts for the next phase of this project.

Potentially radioactively contaminated waters can be stored in portable tanks, such as the large bladder tanks used to store petroleum and potable water in remote locations or tanker trucks. These storage facilities could be used to contain the purged solids from the LAKOS and Separmatic units because these slurries can be pumped into the tanks. The supply of tanker trucks has not been adequately assessed for emergency purposes. Radioactively contaminated dry solids from the barrier can be wrapped within the liner material and hauled onto a truck for transport to an off-site location for treatment and disposal as low-level waste. The exact procedures have not been considered and will require consultation with waste experts and regulators knowledgeable with packaging and transport of contaminated materials.

8. Summary of Recommendations

The conclusions and lessons learned in Section 7 suggest a number of recommendations to enable deployment of an IWAA system during an emergency:

1. Develop tools to help work out logistical and regulatory questions specific to the deployment location of the IWAA system.
2. Maintain a stockpile quantity of suitable vermiculite.
3. Create a suitable separation skid for rapid deployment.
4. Develop tools for responders to locate required equipment and supplies locally.
5. Draft detailed protocol for reuse of wash water.
6. Develop tools and scripts for responders to help coordinate wash water, earth fill, and vermiculite disposal with local authorities.

9. References

1. U.S. Environmental Protection Agency (EPA), *Joint USEPA and Environment Canada Project: Scoping Report on Infrastructure Mitigation via Cs-137 Wash Aid*, 2012. For Official Use Only. Distribution limited to employees of the U.S. federal government and the Canadian federal government.
2. City and County of Denver, *Denver Urban Area Security Initiative* (DUASI), http://www.denvergov.org/Default.aspx?alias=www.denvergov.org/DenverUASI, accessed Aug. 2013.
3. U.S. Department of Homeland Security (DHS), *Wide Area Recovery and Resiliency Program*,(WARRP) http://www.warrp.org, accessed Aug. 2013.
4. U.S. Environmental Protection Agency (EPA), *Irreversible Wash Aid Additive for Cesium Mitigation: Phase II. Selection and/or Modification of COTS Field Portable Waste Water Systems*, 2013. For Official Use Only. Distribution limited to employees of the U.S. federal government.
5. U.S. Environmental Protection Agency (EPA), *Irreversible Wash Aid Additive For Cesium Mitigation – Small-Scale Demonstration and Lessons Learned*, 2013. For Official Use Only. Distribution limited to employees of the U.S. federal government.
6. U.S. Department of Health and Human Services (DHHS), *Sodium Lauryl Sulfate*, http://householdproducts.nlm.nih.gov/cgi-bin/household/brands?tbl=chem&id=78, accessed Aug. 2013.
7. U.S. Environmental Protection Agency (EPA), *Report on the Workshop on Radionuclides in Wastewater Infrastructure Resulting from Emergency Situations*, http://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=515069, accessed Aug. 2013.

10. APPENDIX. Detailed Descriptions of Equipment and Supplies

10.1 Specialty Vermiculite Corporation

SPVCorp.com
Specialty Vermiculite Corp.

Enoree List Pricing
Revised August 15, 2012

For information, please contact Customer Service at (800) 342-2017 between the hours of 8:30am and 5:00pm EST.

VCX Vermiculite Ore Concentrate

Products	Unit Of Sale	Price Per Unit	Price Per Ton
Bulk Shipments:			
VCX 205 Bulk	Ton	$130.20	$130.20
Packaged Goods:			
VCX 205 50# Bags (60/Pallet)	Bag	$4.17	$166.80
VCX 205 3000# Tote	Tote	$267.02	$178.01

Terms and Conditions of Sale:

1. All sales are subject to SPV's Standard Conditions of Sale (see reverse side).
2. Payment Terms: Net 30 Days.
3. All pricing is FOB SPV's plant in Enoree, SC.
4. Pricing includes material, packaging, and pallet

Notes:

1. Minimum order is 60 bags or 1 pallet.
2. For additional information on ordering, packaging or delivery, please contact the SPV Customer Service Center or your sales representative.
3. The palletizing configurations included with this pricing are:
   50# Bags: 60 Bags stretch wrapped on a 40" X 48" wood pallet.
   3000# Tote With Pallet: 1 Tote on a 48" X 48" wood pallet.
4. Typical volumes per load are:

Description:	Unit Of Sale	Unit Volume Per Shipment	Ton Volume Per Shipment
Bulk Rail Shipments:	Ton	95	95
Bulk (LCL) Shipments:	Ton	21	21
50# Bags	Bag	840	21
3000# Tote	Tote	14	21

5. A "Block and Brace" charge of $40.00 will be added for intermodal shipments.

10.2 Sparta Logistics

SPARTA QUOTE SHEET

ARGONNE NATIONAL LABORATORY

ATTN: DEBBIE LEASURE
ARGONNE NATIONAL LABORATORY

FROM: BILLY 773-774-4333 FAX: 773-774-9332
SPARTA LOGISTICS OPS@SPARTAUSA.NET

POINT OF ORIGIN: SPECIALTY VERMICULITE COST CODE: TBD
26383 HWY 221 N
ENOREE, SC 29335

CONTACT: NA
PHONE: 800-342-2017

POINT OF DESTINATION: PARKING LOT DENVER, CO 80202

PICK-UP DATE: 9/7/2012 PICK-UP TIME WINDOW: 0700 - 1400 HOURS

DELIVERY DATE: 9/12/2012 DELIVERY TIME WINDOW: 1000 - 1400 HOURS

PIECES: 3 PALLETS DIMENSIONS: 3 @ 48 X 48 X 54 in

WEIGHT: 9,000 # TOTAL
RATE: $3,489.56

SPECIAL INSTRUCTIONS:SHOW FREIGHT - MUST DELIVER ON WEDNESDAY - 9/12/2012
LIFT-GATE & PALLET JACK ON DELIVERY

LIFT-GATE: ON DELIVERY PALLETIZE & SHRINK WRAP: NA
INSIDE DELIVERY: ON DELIVERY INSURANCE: NA

10.3 Darley and Company

Quotation

Trusted Since 1908

W.S. Darley & Company
Tom Darley
325 Spring Lake Dr.
Itasca, IL 60143
800-323-0244 or 708-345-8050
708-345-8993

DATE
9/31/2012

Quote Date
9/31/2012

Reference

FOB
Shipping Point

PAYMENT TERMS
NET 15 Days

BILL TO:

Argonne National Labratory
Attn: Mike Kaminski
630-252-4777

SHIP TO:

ITEM	QUANTITY	DESCRIPTION	EACH		AMOUNT
1	1	BYPP15501.5-60-DUAL20FT, 1.5", 30 GPM Eductor, 20' pick-up	$489.00		$489.00
2	1	AM080, 1" Nozzle, 30 GPM	$88.95		$88.95
3	1	VB15/10, 1.5" X 1" Valve	$154.00		$154.00
4	1	AM078, 2.5 X 1.5 Gated Wye	$246.95		$246.95
5	2	U273, 1.5" Yellow Hose	$101.95		$203.90
				Estimated Freight	50
				Total	$1,232.80

COMMENTS:

Special Terms:
1. Customer P.O. constitute acceptance of these terms
2. Quote expires 60 days herin

10.4 E.T. Technologies

E.T. Technologies, Inc.
10000 S Dransfeldt Road
Suite 100
Parker, CO 80134

Voice: (303)680-9414
Fax: (303)680-5427

INVOICE

Invoice Number: 105340
Invoice Date: Sep 13, 2012
Page: 1
Duplicate

Bill To:	Ship to:
Argonne National Laboratory 9700 South Cass Avenue Attn: Mike Kaminski Argonne, IL 60439	Argonne National Laboratory 9700 South Cass Avenue Attn: Mike Kaminski Argonne, IL 60439

Customer ID	Customer PO	Payment Terms	
A9700	MIKE KAMINSKI	Net 30 Days	
Sales Rep ID	**Shipping Method**	**Ship Date**	**Due Date**
	12-906-053		10/13/12

Quantity	Item	Description	Unit Price	Amount
		E.T. PROVIDED AN OPERATOR AND A SKID LOADER ON 09-13-12 FOR A DEMONSTRATION LOCATED AT 1417 CALIFORNIA ST IN DENVER, CO.		
1.00		LUMP SUM	965.00	965.00

Check/Credit Memo No:

Subtotal	965.00
Sales Tax	
Total Invoice Amount	965.00
Payment/Credit Applied	
TOTAL	**965.00**

10.5 Mullarkey Associates

MA MULLARKEY ASSOCIATES, INC.

8141 W. 185th Street, Tinley Park, IL 60487

Phone: 708-597-5555 Fax: 708-597-5567

QUOTATION

To: Argonne National Laboratory
Michael D. Kaminski, Ph.D.
9700 S. Cass Avenue
Argonne, IL 60439

DATE: July 30, 2012

In response to your inquiry, we submit the following quotation:

QUANTITY	DESCRIPTION		PRICE
1	IL-0150B	1 ½" MPT Lakos Separator Rated at 45-70 GPM Carbon Steel Construction, ¾" Purge	$510.00 net ea.
1	IL-0125B	1 ¼" MPT Lakos Separator Rated at 28-45 GPM Carbon Steel Construction, ¾" Purge	$490.00 net ea.
1	MBCK-033	Mounting Bracket Kit JLB-0100-0150	$33.00 net ea.
1	VP07-HKV	¾" Manual Visual Purge	$53.50 net ea.
~~1~~	~~[illegible]~~	~~316 SS Bag Housing~~	~~[illegible] ea.~~

Terms:	F.O.B.	Submitted by:	Estimated Ship Date:
1% 10 net 30	Tinley Park, IL	Martin Mullarkey, Jr.	Stock

10.6 Separmatic Fluid Systems

SEPARMATIC
FLUID SYSTEMS

Oct. 1, 2012 Invoice: 27435

Bill To: Argonne National Laboratory
9700 S. Cass Avenue
Lemont, IL 60439

Separmatic has furnished the following equipment for research and development testing for a rental period that included the WARRP Demonstration in Denver and includes follow-up testing in the fall of CY2012 and spring CY2013.

The system includes:

1.) One - 18 inch 24 gpm stainless steel Separmatic Filter Pressure Vessel, complete with eight septums 36 inches in length. Septums will be covered in NSF approved fabric.

2.) One - 100 gallon fiberglass tank piped for recirculation

3.) One - Mixer installed on the recirculation tank.

4.) One - Flow Meter

5.) Two - Gauges, one installed on the low side of the pressure vessel, one installed on the high side of the pressure vessel.

6.) One - Aqua Sensor Turbidity Meter. This precise instrument is capable of reading turbidity in units of less than 1/100th of one NTU.

7.) Three - Sample points installed within the system. One prior to the pre-filter, one installed after the pre-filter, and one installed after the Separmatic Filter Pressure Vessel. All three samples points will be capable of delivering samples with tubing individually run to the Aqua Sensor.

8.) One - Pump to pressurize the Separmatic System

9.) Complete custom pipe configuration including, but not limited to, eight 2" valves, three 1-1/2" valves, unions, reducers, and drains. All plumbing shall consist of NSF Approved Food Grade Schedule 80 PVC.

10.) The installation of one Lakos Pre-Filter.

W146 N5800 Enterprise Ave.
Menomonee Falls, WI 53051

Phone 414-466-5200 Fax 414-466-5258
www.separmaticsystems.com

Oct. 1, 2012

Invoice: 27435
(cont.)

11.) Completely wired, including GFI's and circuit breakers

12.) All of the above to be mounted on a 6 foot square fiberglass skid.

Separmatic, LLC also agrees to furnish three technicians for the rental period. All technicians' expenses, including delivery of unit, travel, hotel, and food are included in the rental price.

Separmatic agrees to supply the above rental equipment for the sum of **$12,000.00.**

You may contact Jack at 262-527-7411 (cell) or Cindy at 414-466-5200 (office).

Thank You.

Please Note: Checks to be made out to Separmatic, LLC.

W146 N5800 Enterprise Ave.
Menomonee Falls, WI 53051

Phone 414-466-5200 Fax 414-466-5258
www.separmaticsystems.com

Nuclear Engineering Division
Argonne National Laboratory
9700 South Cass Avenue, Bldg. 205
Argonne, IL 60439-4854

www.anl.gov

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laboratory managed by UChicago Argonne, LLC